AD-A082 236   ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA   F/G 8/2

CARTOGRAPHIC RASTER PROCESSING PROGRAMS AT USAETL,(U)

JAN 80 R A CLARK

UNCLASSIFIED   ETL-R005   NL

1 OF 1

AD
A082236

END

DATE
FILMED
4-80

DTIC

LEVEL II

U.S. ARMY

ENGINEER TOPOGRAPHIC LABORATORIES

FORT BELVOIR, VIRGINIA

AD A082236

R-005

CARTOGRAPHIC RASTER PROCESSING PROGRAMS AT USAETL

by

RICHARD A. CLARK

Approved for public release; distribution unlimited

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
ETL-R-005

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
6 CARTOGRAPHIC RASTER PROCESSING PROGRAMS AT USAETL

5. TYPE OF REPORT & PERIOD COVERED
Paper

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
10 Richard A. Clark

8. CONTRACT OR GRANT NUMBER(s)
12 19

9. PERFORMING ORGANIZATION NAME AND ADDRESS
USA Engineer Topographic Laboratories
Fort Belvoir, VA 22060

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
USA Engineer Topographic Laboratories
Fort Belvoir, VA 22060

12. REPORT DATE
11 8 Jan[illegible]980

13. NUMBER OF PAGES
16

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
14 ETL-[illegible]

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
Approved for public release; distribution unlimited.

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
1. Raster processing
2. STARAN* associative array processor
3. vector-to-raster
4. raster symbolization
5. Digital Laster Platemaker

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The raster processing activities at USAETL have been concerned with both hardware and software development aimed at high-speed generation of topographic data base information and graphic map production. Early work with raster digitizing techniques resulted in the development of the Cartographic Scanner/Plotter which provides a multi-resolution, rapid capability of digitizing or film plotting. Software to process these raster data has been developed for sequential computers as well as for the STARAN: associative array processor. Recently completed programs for the STARAN permit the processing of raster-scanned contour sheets, the

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED JOB

403192

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

semi-automatic determination and tagging of elevations for the contours, and INTERPOLATION OF THESE TAGGED CONTOURS INTO A UNIFORM GRID OF ELEVATIONS. Work has also been started on algorithm development for automatic detection of cartographically symbolized raster scan data. STRAPS programming improvements are under way which will provide expanded capabilities in the vector-to-raster and raster symbolization areas. The soon to be delivered Digital Laser Platemaker will provide a totally new capability to go directly from raster formatted data to press plates, eliminating the film preparation stages entirely. An inherent capability also exists in the laser platemaker to produce quick, self-developing proof plots and conventionalfilm plots for back-up purposes, as weel as to receive data via satellite for remote operations.

* T. M. Goodyear Aerospace Corporation, Akron, Ohio 44315

A

CARTOGRAPHIC RASTER PROCESSING PROGRAMS AT USAETL

Richard A. Clark
Sr. Mechanical Engineer
Automated Cartography Branch
U.S. Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060

BIOGRAPHICAL SKETCH

Richard A. Clark is a graduate of Rochester Institute of Technology with a B.S. degree in Mechanical Engineering. He has been with the U.S. Army Engineer Topographic Laboratories since 1967, working as a Project Engineer for the development of hardware and software for automated cartography. He has served as the USAETL representative to the DMA AD-HOC Committee on Automated Cartography in matters pertaining to raster processing, since 1972. Prior to government service he was associated with Eastman Kodak Co., and General Precision Inc., as a Project Engineer on optical/mechanical systems. Mr. Clark has also done graduate work in systems management at U.S.C. and is a graduate of Control Data Institute.

ABSTRACT

The raster processing activities at USAETL have been concerned with both hardware and software development aimed at high-speed generation of topographic data base information and graphic map production. Early work with raster digitizing techniques resulted in the development of the Cartographic Scanner/Plotter which provides a multi-resolution, rapid capability of digitizing or film plotting. Software to process these raster data has been developed for sequential computers as well as for the STARAN* associative array processor. Recently completed programs for the STARAN permit the processing of raster-scanned contour sheets, the semi-automatic determination and tagging of elevations for the contours, and interpolation of these tagged contours into a uniform grid of elevations. Work has also been started on algorithm development for automatic detection of cartographically symbolized raster scan data. STRAPS programming improvements are under way which will provide expanded capabilities in the vector-to-raster and raster symbolization areas. The soon to be delivered Digital Laser Platemaker will provide a totally new capability to go directly from raster formatted data to press plates, eliminating the film preparation stages entirely. An inherent capability also exists in the laser platemaker to produce quick, self-developing proof plots and conventional film plots for back-up purposes, as well as to receive data via satellite for remote operations.

---

* T. M. Goodyear Aerospace Corporation, Akron, Ohio 44315

INTRODUCTION

The Automated Cartography Program at the U.S. Army Engineer Topographic Laboratories (USAETL), Fort Belvoir, Virginia, has been concerned with the development of techniques for digitizing graphic map data and processing these data for data-base applications and/or for new graphic map production. One portion of this effort over the past 10 years has been directed toward raster processing, which has long been recognized as having the potential for rapid digitizing, and processing of high-density line work, such as is found on contour sheets. For instance, while a high-density contour sheet containing 11,000 inches of line work typically requires in excess of 80 hours of X-Y digitizing, the same sheet can be digitized via raster scanning in 1/2 hour or less. USAETL's activities have involved, in addition to the development of hardware for raster digitizing, the writing of computer software to process these data, and the development of hardware to convert these processed data back to graphic form.

HARDWARE AND SOFTWARE DEVELOPMENTS

Raster Scanner/Plotter Hardware

A cartographic scanner/plotter was developed for USAETL by IBM Corp., in 1971-72 (Figure 1). This device was designed to combine the functions of scanning (raster digitizing) cartographic manuscripts and plotting cartographic color-separation films. This scanner/plotter, which was a forerunner of drum scanners and plotters currently in use at the Defense Mapping Agency Centers, permitted the scanning or plotting of 24-by-30 inch formats using a 1-mil, 2-mil, or 4-mil pixel size. This hardware which is still in use at USAETL operates off-line, that is, its input and output are via magnetic tapes which must be processed on a computer. Typical scan times for full format-sized sheets are from 30 minutes for a 4-mil scan (viz, 250 pixel samples per inch) to 120 minutes for a 1-mil scan. Scanning illumination and detection is by a conventional tungsten-halogen lamp and photomultiplier arrangement. Plotting is performed by imaging the output of a Light Emitting Diode (LED) array onto red-sensitive film. While this method of plotting has proven to be very reliable and produces high-quality images, the film used dictates total darkness for loading and unloading, and the black-to-white contrast is not as good as with graphic arts type films. Tests were performed to show the quality level of printed graphics produced from images plotted on the scanner/plotter. These tests indicated that 4-mil pixels produced a noticeable stair-case effect on line work, 2-mil pixels were just noticeable, and 1-mil pixels could not be detected on the printed sheet due to normal ink-spread characteristics.

Early Raster Software Development

Early programming to support the raster hardware was based around existing large sequential computers. Processing of scanned data consisted mainly of reading in the magnetic tapes, decoding the run-length coding, which was used to com-

press the data, thinning image lines to unity width, line following, vector chaining, and outputting the resultant vector files. These files could then be used to support data base operations, could become input for vector symbolizing and plotting operations, or could continue on through the raster programs to be converted back to raster format and subsequently be symbolized to cartographic standards and output as raster plot tapes. This software was written for the USAETL CDC-6400 computer and demonstrated many of the problems associated with processing large raster data files. The 11 feature manuscripts which were required to produce the Lake Istokpoga sheet (Figure 2) were processed far enough on the 6400 to get timing estimates (Figure 3). These timing estimates indicated that unrealistically long computer runs would be required to process even simple images and that a radically different approach was needed.

Associative Array Processor Software

Investigations into the possible application of the STARAN associative array processor, starting in 1973, showed the potential for high-speed processing of raster scan data. The STARAN utilizes a series of arrays which, along with the processor control section, permit multi-dimensional access to all data stored in these arrays on a content addressable basis rather than on a coordinate addressable basis as found in conventional sequential computers. The above mentioned Lake Istokpoga manuscripts were completely processed on the STARAN and the times shown in Figure 4 were recorded. These times represent about a 4 x improvement over those estimated from the sequential tests when input/output and central processor times are compared. If just central processor times are examined, which is perhaps a truer comparison, the improvement is 22 x. In this test, the 11 hand-drawn manuscripts were scanned with a 4-mil pixel size, converted and merged into symbolized raster plot tapes from which four separation negatives were produced and the sheet subsequently printed. In 1978, an advanced developmental version of the STARAN programs was installed on the USAETL STARAN/6400 computer complex. The STARAN at USAETL is operated as a peripheral processor on the CDC 6400 and utilizes the 6400's magnetic tape units and disks. Programs are therefore entered as batch jobs on the 6400 and can take advantage of the 6400 for operations such as tape input/output and data transfers on disc. This program is called STRAPS (Staran Raster Processing Software) and has been used to obtain further test data as well as to proof raster data from various scanners. STRAPS will process data in the 1-mil, 2-mil or 4-mil pixel size from the USAETL scanner, or in the 25 micrometer pixel size common to the DMA scanners. Figure 5 indicates the programs major modules. Figure 6 is a tabulation of several tests on STRAPS at different pixel sizes. It is interesting to note that processing times are not directly proportional to data density but appear to be more a function of the total number of pixels involved. Raster processing hardware and software times are therefore not data density dependent. And, other things being equal, raster processing is most cost-effective with very dense line work, such as contours.

Contour Tagging and Gridding Software

Software was delivered in late 1979 which operates on the STARAN/6400 and is designed to process raster scanned contour sheets. This software is called CONTAGRID (Contour Tagging and Gridding) and performs raster-to-vector conversion, elevation tag association in a semi-automatic mode, and the interpolation of these tagged contours into a uniform grid of elevations. CONTAGRID was designed to augment an existing system at DMA which utilizes manual digitizers to obtain tagged vectors of the contour lines, an operation requiring an average of 80 hours of operator-intensive time. The philosophy behind CONTAGRID is that contours, if properly drawn, follow specific rules and therefore should be readily amenable to computer processing. Having already demonstrated that raster-to-vector conversion can be performed rapidly with the associative array processor, it remained to be determined if the contour lines (10,000 inches or more on some sheets) could be examined and tagged by elevation without excessive human intervention and within a reasonable amount of computer time. The goals established for this development were to process from graphic to elevation grid, one 1/50,000, 15-minute sheet in 8 hours or less, with less than 40 percent manual assignment of elevations in an interactive mode.

Figure 7 shows the major modules that make up CONTAGRID. TAPEIN reads run-length coded raster scan data tapes in DMA or USAETL format, and copies these data to disk. In the case of the two-tape DMA format (odd/even tapes) the records are merged onto the disk file. This module also requires image descriptors to be input via data cards. Image descriptors consist of information such as processing resolution, size of image, index and non-index contour line width, contour interval, min/max elevation and windowing parameters. TAPEIN is performed entirely on the CDC 6400.

BILDVEC uses the image data and descriptors to generate array vectors and linked master vectors. It then uses the linked master vector data to perform automatic editing and vector classification. Both STARAN and the 6400 are required for most of the operations in this module.

PLOTGEN uses the vector classification files, the linked master vector data, and the array vector data base to produce a CALCOMP plot tape for subsequent manual editing. This task is performed entirely on the 6400.

VALDVEC carries out the manual editing specified by the user which can consist of the following edit directives: CHANGE, DELETE, JOIN, and, if a CALCOMP plot file is desired, PLOT. Manual editing rather than interactive editing was chosen for the initial CONTAGRID development as the software emphasis was intended to be on development of the algorithms for automatic tagging. Future versions of CONTAGRID will undoubtedly utilize interactive edit techniques to speed up the VALDEC operations. VALDEC is primarily a 6400 task but the STARAN is required for the JOIN directive.

SQUEEZE is executed to build contour vectors from master

vector data. Contour vectors are vector files ordered by elevations. This module operates entirely on the 6400.

TAGOPN generates, stores, and displays an elevation tag for each boundary contour vector. A list of boundary index contour elevations is input to this module and is the basis for the calculation of non-index boundary contour elevations. TAGOPN is executed on the STARAN and 6400.

EDITAGS is a 6400 program which allows the user to display, correct, and store elevation tag lists. This program is also used after TAGCLO to inspect and edit the closed contour tag lists.

TAGCLO is the closed contour (non-boundary contours) tagging routine. A complete set of boundary contour tags is required prior to executing this program. Closed contours are tagged by satisfying the following criteria: (1) relative order of closed contours within a set is established, (2) center-most contours of a set are identified, and (3) the elevations of 2 open contours adjacent to the set are known. The STARAN and 6400 are used for this operation.

PLOTAGS is carried out to produce a CALCOMP plot tape of the contour vectors parsed, or sorted, by elevations, and to create a data base for subsequent gridding validation operations. The plot tape is blocked by contour bands such that plotter pen changes can be accommodated for color keying, a technique which greatly facilitates visual proofing. The data base creation involves the formatting of the contour vector lists into a specific DMA vector form, as well as leaving them in the CONTAGRID-unique format. This is a 6400 program.

GRIDEM is the final module which interpolates the contour vector data and supplmentary saddle and ridge vector data into a uniform grid of elevation values. A bi-axial linear interpolation algorithm is employed which takes advantage of the STARAN's parallel processing capabilities.

At the time this paper was written, initial tests had been performed on CONTAGRID. These tests consisted of processing a 4-by 4-inch section of a medium-density contour sheet from raster scan to elevation grid. The test results are tabulated in Figure 8 and show the central processor (CP) and input/output (I/O) times for each major module. Insufficient data exists at this time to attempt to predict the CP and I/O times that will be required for an 18-by 22-inch sheet. Similarly, only subjective evaluations of the resulting gridded data have been made, but the agreement with DMA elevation data for the same area is remarkably good. Comparison was made by displaying iso-elevation bands from each grid set on a color COMTAL in flicker-fashion to detect differences. As testing proceeds, processing times for larger data sets, automatic tagging success rates, and grid accuracy figures will be determined. As for the future, modifications to CONTAGRID will probably include, in addition to the previously mentioned interactive editing, features which make the algorithms less sensitive to non-uniform line weights.

NEW SOFTWARE DEVELOPMENTS

Two other ongoing raster software projects at USAETL, due to be completed in 1980, also involve the CDC 6400 and STARAN. One is an investigation into basic algorithms for detecting cartographically symbolized features existing on raster scanned sheets. This work will attempt to design the logic for separating dual casing roads, railroads, depression contours, and broken line symbology, existing on the same raster data set. If successful, this work could lead to the rapid digitizing and tagging of existing planimetric separation sheets, a necessary precursor to digital map revision. It is also anticipated that the successful algorithms may also be applicable to feature separation of raster scanned compilation manuscripts where only very basic symbolization has been performed.

The other ongoing work involves improvements to the previously discussed STRAPS program. The original STRAPS development gave priority to raster-to-vector conversion operations and much time was spent optimizing these routines for the USAETL computer configuration. Initial routines were also written which performed vector-to-raster operations and permitted various line symbology to be created in the raster image. The current work will attempt to optimize the vector-to-raster software to reduce execution times. In conjunction with this, the whole symbolization process, from raster digitizing and storage in the symbol library, to look-up and placement by the program, will be improved and expanded. While digital data bases containing elevation matrices, topographic features, terrain information, etc., may be the end product for many in the mapping field today, there is still a requirement for many others to supply graphics. Raster plotting offers an extremely fast method of going from digital to graphic, and vector-to-raster conversion with subsequent symbolization is the key to this for the majority of mappers whose digital data, for reasons of economics, exists in vector form.

DIGITAL LASER PLATEMAKER

In discussing raster plotting for mapping applications, one is typically referring to hardware which converts digital data into some form of electromagnetic energy for exposing film, which in turn can be used to transfer an image onto a lithographic press plate. A new short-cut to the press plate, spawned by the newspaper printing industry, is called a laser platemaker. Most newspaper applications involve the scanning or reading of a graphic paste-up in facsimile fashion, and the real-time or near real-time writing of the image directly onto a lithographic press plate. A high-powered laser is typically required to sufficiently expose the press plate. USAETL is developing for the Defense Mapping Agency a Laser Platemaker (LPM) for digital mapping applications. This equipment, (Figure 9) which will be delivered to USAETL in early 1980, accommodates DMA's large 4-by 5-foot press plates and uses digital data in raster format to control an ultra-violet laser for exposure of plates in 15 minutes or less.

Digital images will be read by the LPM's 6250 B.P.I. tape units and operations will be sequenced by a DEC PDP 11/34 controller. Very high data rates (VIZ, 2.8 mega-bits per sec.) are required to achieve the 15 minute exposure time for the full-image format of approximately 42 by 59 inches. This fact is better understood when it is realized that 2.5 x 10^9 pixels make up the image. That means that 2.5 billion image pixels have to be transferred from tape in 15 minutes. Data can be in binary (1-bit per pixel) or 1-byte run length code and can be intermixed within an image. To assist the computer in achieving these data rates, the data is blocked into 16 K-byte records. This means that many raster scan lines of data will be packed into one physical record on tape and actual tape read time will be substantially reduced. Run length coded data, if blocked by single scan lines, is characterized by many very short records, which contribute to high input-output times.

While the LPM will write directly onto lithographic plates and thus reap the benefits of eliminating costly silver halide films, the LPM will also permit the operator to expose conventional graphic arts film if desired for archival purposes. Proof plots can also be made onto self-developing paper, such as Dylux.* The LPM is being developed for DMA's production plant operations with its magnetic tape units attached, but the capability to receive data via satellite is inherent. Some newspapers are currently using satellite transmission of pages on a daily basis, and future mapping and charting will almost certainly involve remote print plant operations.

SUMMARY

The results of the work in raster processing accomplished thus far at USAETL, have shown that while some problems are yet to be solved, there are many reasons to be optimistic over the potentials of the hardware and software to greatly speed up the mapping process.

As we enter the decade of the 1980s it is anticipated that more and more of the mapping community will turn to raster processing for automated cartographic functions, and that the level of sophistication in hardware and software will greatly exceed anything we have envisioned in the 1970s.

* T.M.E.I. DuPont & Company, Wilmington, Delaware

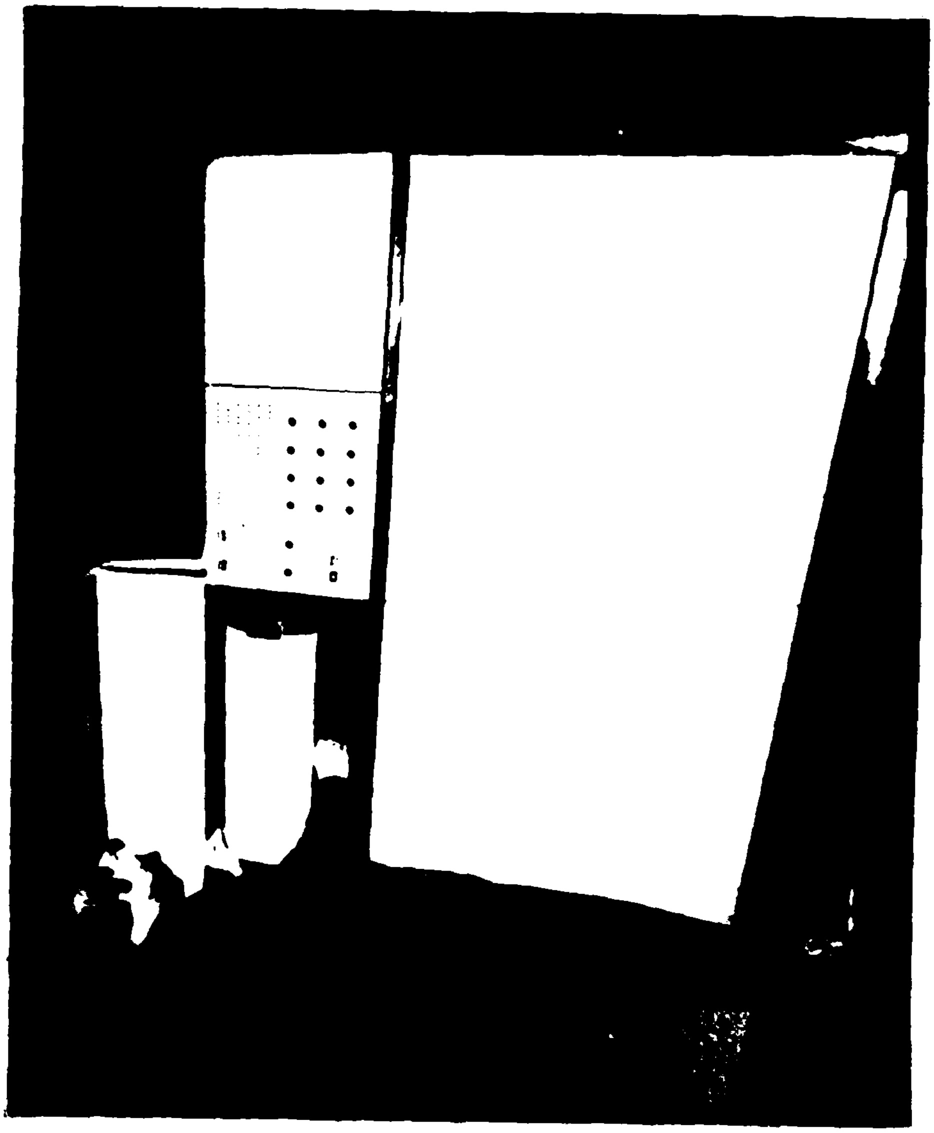


FIGURE 1

FIG 1

LAKE ISTOKPOGA

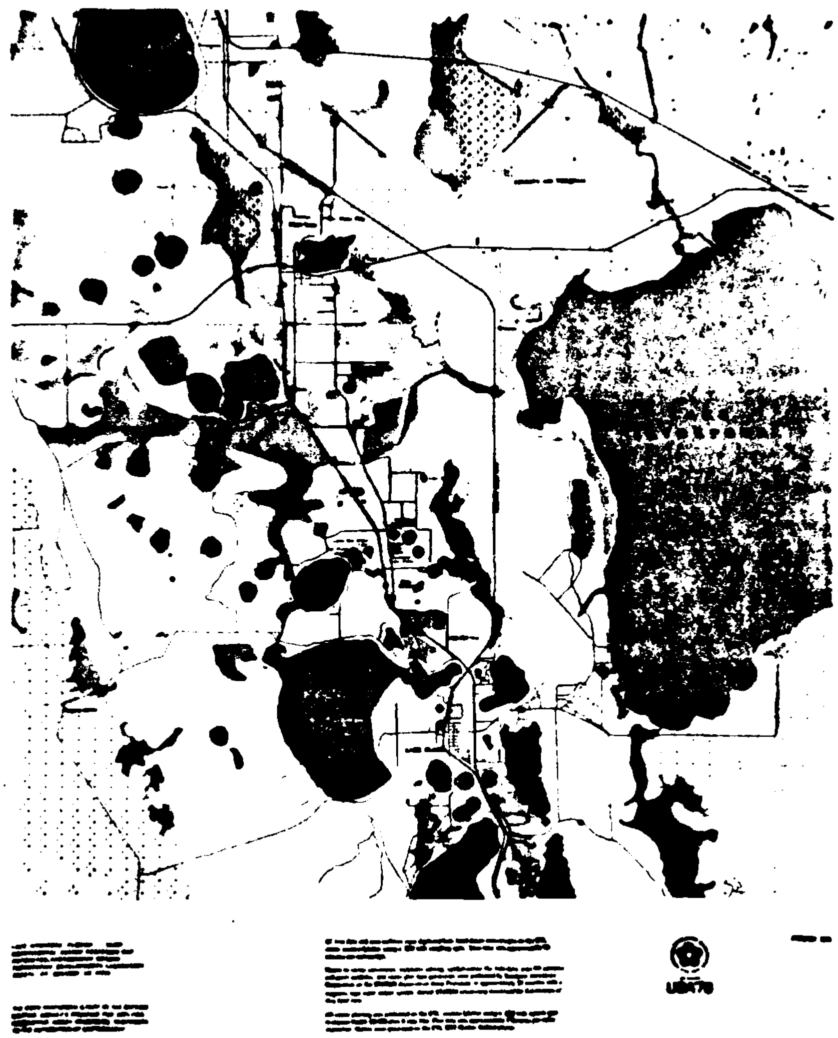


FIGURE 2

LAKE ISTOKPOGA RASTER PROCESSING TIMES

COMPUTER: CDC 6400

DATA: 4-MIL SCAN, 20"x20", 25x10^6 PIXELS

Data Class	Raster to Vector	Vector to Raster	Total
1st Class Roads	8.2 min.	4.2 min.	12.4 min.
2nd Class Roads	7.4	4.5	11.9
3rd Class Roads	10.6	2.6	13.2
Trails	5.9	2.2	8.1
Railroads	6.1	2.1	8.2
Perennial Streams	9.8	2.3	12.1
Intermittent Streams	5.2	1.9	7.1
Woods	14.4	6.3*	20.7
Orchards	11.3	6.3*	17.6
Swamps	11.3	6.3*	17.6
Lakes	13.9	6.3*	20.2
		TOTAL =	149.1 min.

(75 min CP + 74 min I/O)

*Estimated

FIGURE 3

LAKE ISTOKPOGA RASTER PROCESSING TIMES

COMPUTER: STARAN A.A.P.

DATA: 4-MIL SCAN, 20"x20", 25x10^6 PIXELS

DATA CLASS	RASTER TO VECTOR	VECTOR TO RASTER	TOTAL
1ST CLASS ROADS	1.8 MIN	1.8 MIN	3.6 MIN
2ND CLASS ROADS	1.8	1.8	3.6
3RD CLASS ROADS	1.8	1.8	3.6
TRAILS	1.8	1.8	3.6
RAILROADS	1.8	1.8	3.6
PERENNIAL STREAMS	1.8	1.8	3.6
INTERMITTENT STREAMS	1.8	1.8	3.6
WOODS	1.8	1.8	3.6
ORCHARDS	1.8	1.8	3.6
SWAMPS	1.8	1.8	3.6
LAKES	1.8	1.8	3.6
		TOTAL =	39.6 MIN

(3.4 MIN CP TIME)*

*CP TIME CONCURRENT WITH I/O

FIGURE 4

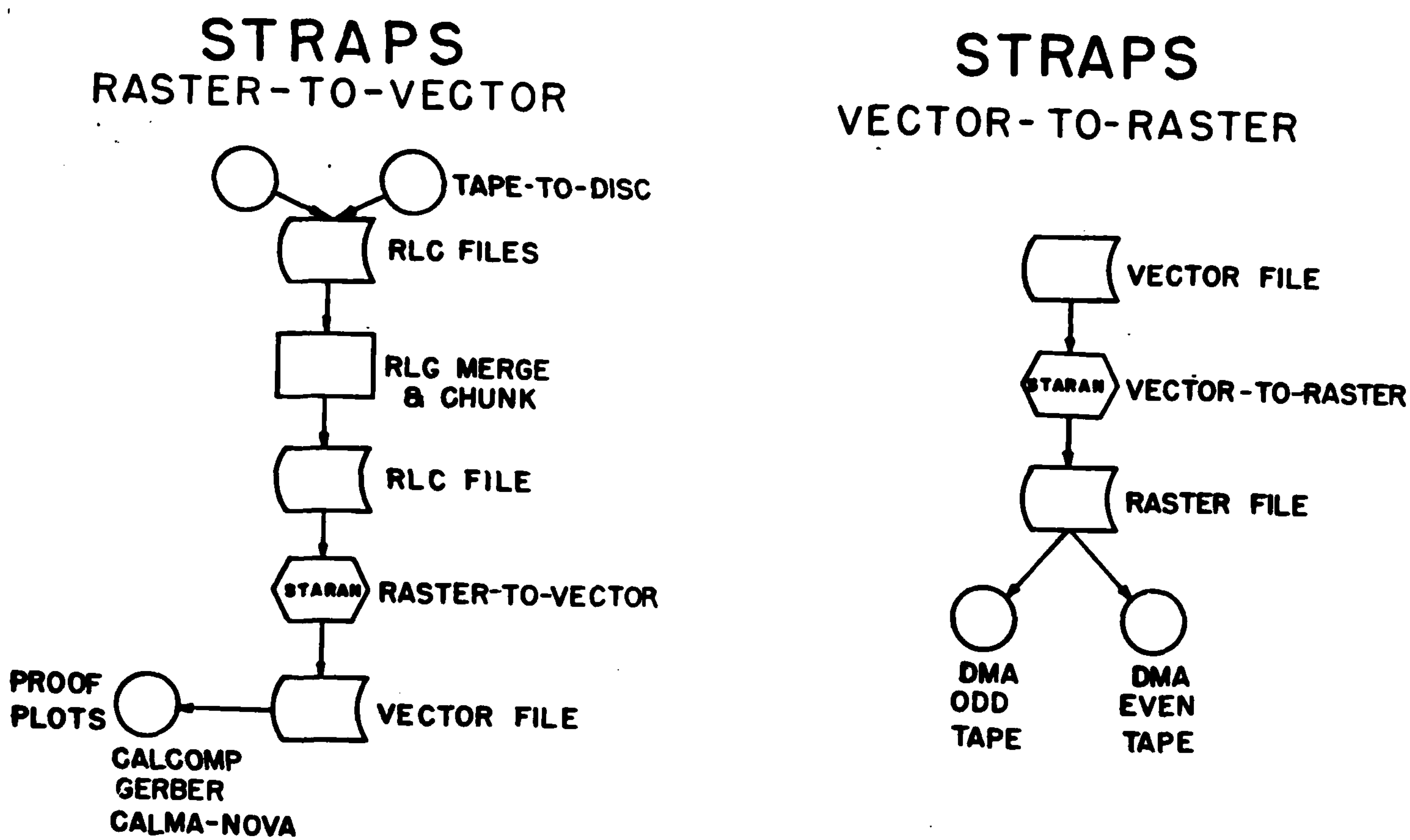

STRAPS
RASTER-TO-VECTOR
TAPE-TO-DISC
RLC FILES
RLG MERGE
& CHUNK
RLC FILE
STARAN
RASTER-TO-VECTOR
VECTOR FILE
PROOF
PLOTS
CALCOMP
GERBER
CALMA-NOVA
STRAPS
VECTOR-TO-RASTER
VECTOR FILE
STARAN
VECTOR-TO-RASTER
RASTER FILE
DMA
ODD
TAPE
DMA
EVEN
TAPE

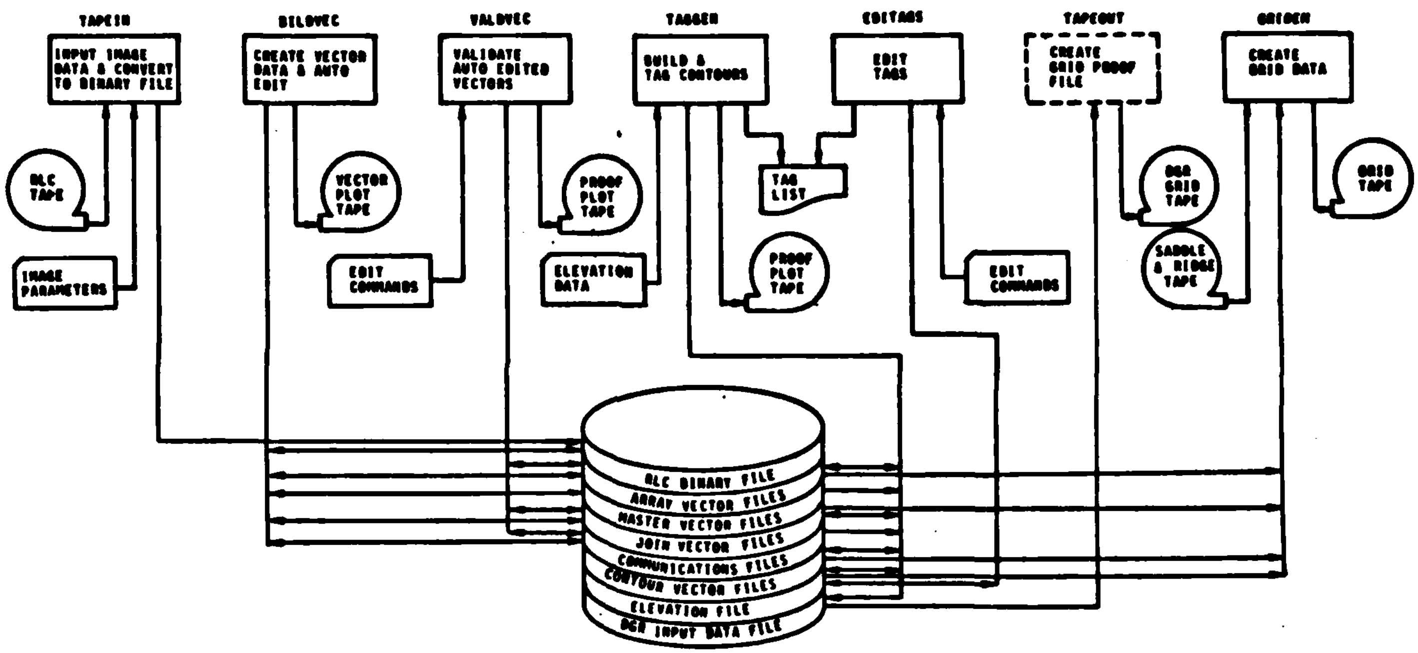
FIGURE 5

STARAN RASTER PROCESSING SOFTWARE (STRAPS)

TEST RESULTS

SUBJECT	Resolution Mils (μ)	Image Size (inches)	No. of Pixels	CDC 6400/STARAN in seconds								Pixels per Second	No. of Lineal Inches	Input Line Width(mils
				Tape Input		Merge & Chunk File		Raster to Vector		Vector to Raster				
				CP	I/O	CP	I/O	CP	I/O	CP	I/O			
Shiraz Roads	4 (100)	20x23	$2.8x10^7$	13	60	38	8	121	41	N/A	N/A	$1.8x10^5$	257	12-20
Willow Springs Roads	4 (100)	18x22	$2.6x10^7$	13	62	40	9	158	65	N/A	N/A	$1.6x10^5$	1247	25-32
Cartographic Test Standard	2 (50)	18x18	$8.3x10^7$	20	104	92	15	366	102	N/A	N/A	$2.2x10^5$	553	2-15
HTC Contours	2 (50)	17x21	$9.2x10^7$	25	137	197	26	614	762	2724	118	$1.5x10^5$	5375	10-13
Willow Springs Roads	1 (25)	18x20	$3.6x10^8$	36	?	328	?	1638	401	N/A	N/A	$2.2x10^5$	1055	25-32
Cartographic Test Standard	1 (25)	17x17	$2.9x10^8$	38	200	239	30	1106	260	N/A	N/A	$2.5x10^5$	543	2-15

FIGURE 6



CONTOUR TAGGING AND GRIDDING PROGRAM (CONTAGRID)

FIGURE 7

CONTAGRID EXECUTION TIMES

DATE: 25μ scan, 4"x4", 16.5 x 10^6 pixels

MODULE	DESCRIPTION	MACHINES UTILIZED		C.P. TIME (SECS)	I/O TIME (SECS)
		CDC 6400	STARAN		
TAPEIN	Merged DMA R.L.C. Files on disk	X		26.1	20.3
BILDVEC	Convert Rast-To-Vector, build master vectors, auto edit	X	X	24.82	543.8
VALDVEC	Performs manual editing clean up	X	X	2.26	21.9
PLOTGEN	Generates plots of edited data	X		143.1	243.0
SQUEEZE	Generates contour vectors from master vectors	X		4.95	25.0
TAGOPN	TAGS open (boundary) contour vectors	X	X	0.54	6.25
EDITAGS	Edits open vectors	X		0.87	1.6
TAGCLO	TAGS closed contour vectors	X	X	4.53	9.6
EDITAGS	Edits closed contour vectors	X		0.86	1.6
TAPEOUT	Generated D.G.R. formatted tape	X		33.5	15.8
PLOTAGS	Plots tagged contour vectors by elevations	X		70.9	113.7
GRID	Performs gridding	X	X	68.7	98.6

FIGURE 8

Fig 7 CLAIL

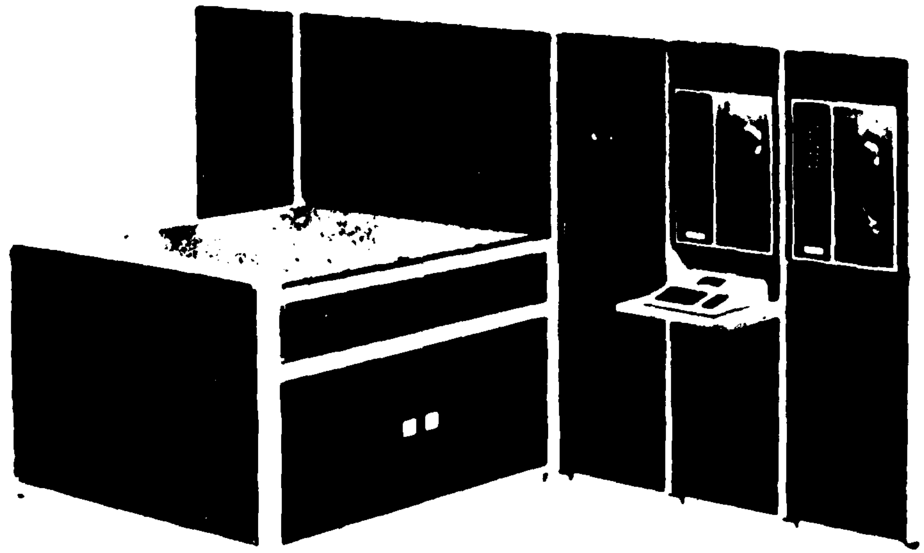


FIGURE 9